group velocity $V_g = d\omega/dk$ tends to zero at the band edges and phase velocity $V_\phi = \omega/k$ tends toward infinity at the different values of $\omega d/c$ where kd approaches zero. V_ϕ tends to infinity for the values of $\omega d/c \cong 5.4$ and 6.2 in case of air–glass [see Figure 6(a)], where as in case of air–zinc sulphide [Figure 6(b)] $\omega d/c \cong 4.8$ and 6.0, respectively. Thus one can visualize the formation of standing waves at the band edges, as found in the solid state. Hence the refractive index seems to be zero at these values.

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A SHORTED PATCH ANTENNA WITH AN L-SHAPED GROUND PLANE FOR INTERNAL MOBILE HANDSET ANTENNAS

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ABSTRACT: *This letter presents a novel shorted patch antenna for applications as internal mobile handset antennas. Instead of a conventional simple ground plane, the proposed antenna uses an L-shaped ground plane, which effectively decreases the antenna's backward radiation and enhances the antenna gain. A prototype of the proposed antenna suitable for operating in the UMTS (1920–2170 MHz) band has been constructed, and experimental results are presented. The constructed prototype occupies a small volume of $30 \times 17 \times 7$ mm^3, which makes it suitable to be employed as an internal mobile handset antenna, and shows a peak antenna gain of about 3.5 dBi, with gain variations less than 1.2 dBi for frequencies within the UMTS band.* © 2002 Wiley Periodicals, Inc. Microwave Opt Technol Lett 33: 314–316, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.10305

Key words: *antennas; shorted patch antennas; mobile antennas*

1. INTRODUCTION

Shorted patch antennas or planar inverted-F antennas for applications as internal mobile handset antennas have recently been demonstrated, and a variety of designs have also been reported in the open literature [1–8]. These reported designs, however, are mainly with a simple ground plane. This letter proposes a novel shorted patch antenna design with an L-shaped ground plane to enhance the antenna performance. It has been observed that, mainly because of the use of an L-shaped ground plane, the backward radiation of the proposed antenna is reduced, which could reduce in the power absorption in the user's head. In addition, the antenna's peak antenna gain is also enhanced. In this study, details of the proposed antenna design are described, and experimental results of a constructed prototype suitable for operating in the UMTS (Universal Mobile Telecommunication System, 1920–2170 MHz) band are presented. The experimental results are also compared with those of the corresponding conventional shorted patch antennas with a simple ground plane.

2. ANTENNA DESIGN

Figure 1(a) shows the geometry of the conventional shorted patch antennas with a simple ground plane for an internal mobile handset antenna, and the proposed antenna with an L-shaped ground plane is presented in Figure 1(b). In both geometries, the simple ground

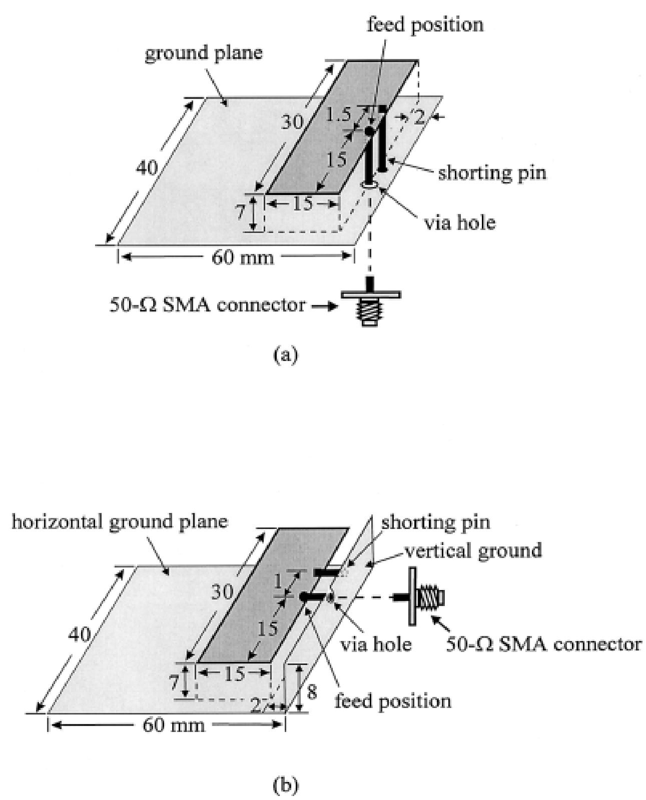

Figure 1 Geometries of the shorted patch antennas for internal mobile handset antennas. (a) The conventional design with a simple ground plane [1]. (b) The proposed design with an L-shaped ground plane

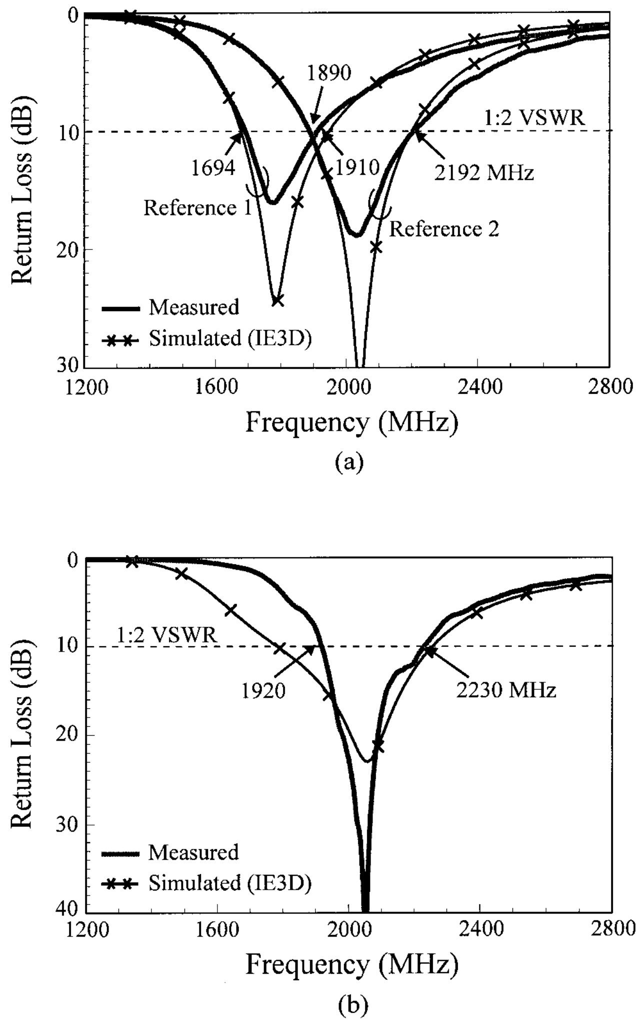

Figure 2 Measured and simulated return loss against frequency. (a) The conventional design [Reference 1: patch size 15 × 30 mm^2 as described in Figure 1(a); Reference 2: patch size 13 × 26 mm^2; other parameters for both References 1 and 2 are the same and are given in Figure 1(a)]. (b) The proposed design with dimensions given in Figure 1(b)

plane in Figure 1(a) and the horizontal ground plane in Figure 1(b) have the same dimensions (60 × 40 mm^2) and can be considered to be the ground plane of a practical mobile handset. An additional vertical ground is added to the edge of the horizontal ground plane in the proposed design to enhance the antenna performance. In this case, the vertical ground and the horizontal ground plane form an L-shaped ground plane for the proposed design. In addition, due to the additional vertical ground, the coax feed can be placed in the same plane as the radiating patch, as seen in Figure 1(b) or below the horizontal ground plane as seen in Figure 1(a), which gives the proposed antenna flexible feed arrangements compared to conventional design.

It should also be noted that the dimensions given in Figure 1(b) are for achieving UMTS band operation. The antenna is fed at the center of the edge of the shorted patch, which has dimensions of 30 × 15 mm^2 and is above the horizontal ground plane with a height of 7 mm. The shorted patch is also placed close to the vertical ground to reduce the required probe-pin length of the coplanar coax feed, which makes impedance matching of the proposed antenna over a wide bandwidth easy to achieve. In the present design, the distance between the vertical ground and the

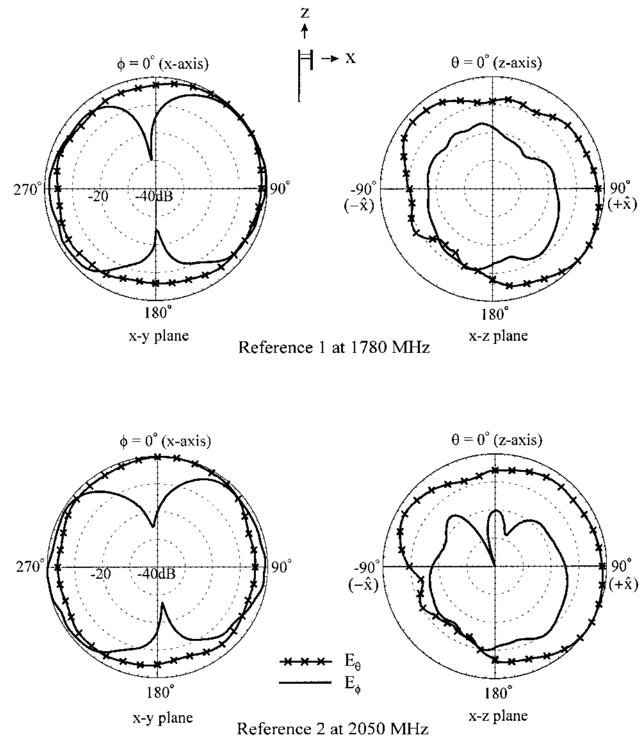

Figure 3 Measured radiation patterns for the reference antennas at resonance

patch edge is 2 mm, and the shorting-pin position is 1 mm away from the feed position. Also note that, for the corresponding conventional design shown in Figure 1(a), all the dimensions are the same as those given in Figure 1(b), except that the distance between the shorting pin and the feed position is 1.5 mm, to achieve good impedance matching.

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figures 2(a) and 2(b) show the measured and simulated return loss for the corresponding conventional design [1, 2] and the proposed design. Good agreement between the measurement and the simulation for References 1 and 2 shown in Figure 2(a) is obtained. As for the proposed design in Figure 2(b), the measured data in general also agrees with the simulated results. It is first seen that the proposed design has a wide impedance bandwidth (1:2 VSWR) of 310 MHz (1920–2230 MHz), which covers the required operating bandwidth of the UMTS band. It should also be

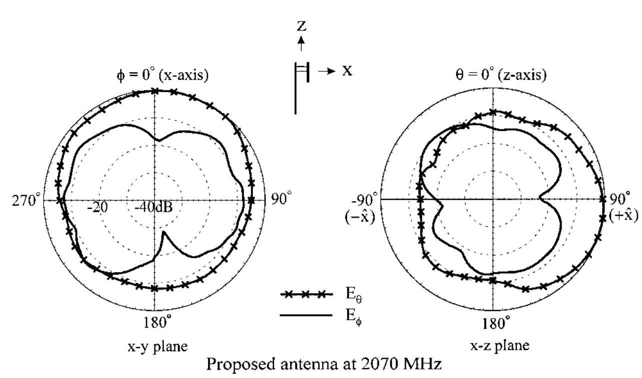

Figure 4 Measured radiation patterns for the proposed antenna at resonance

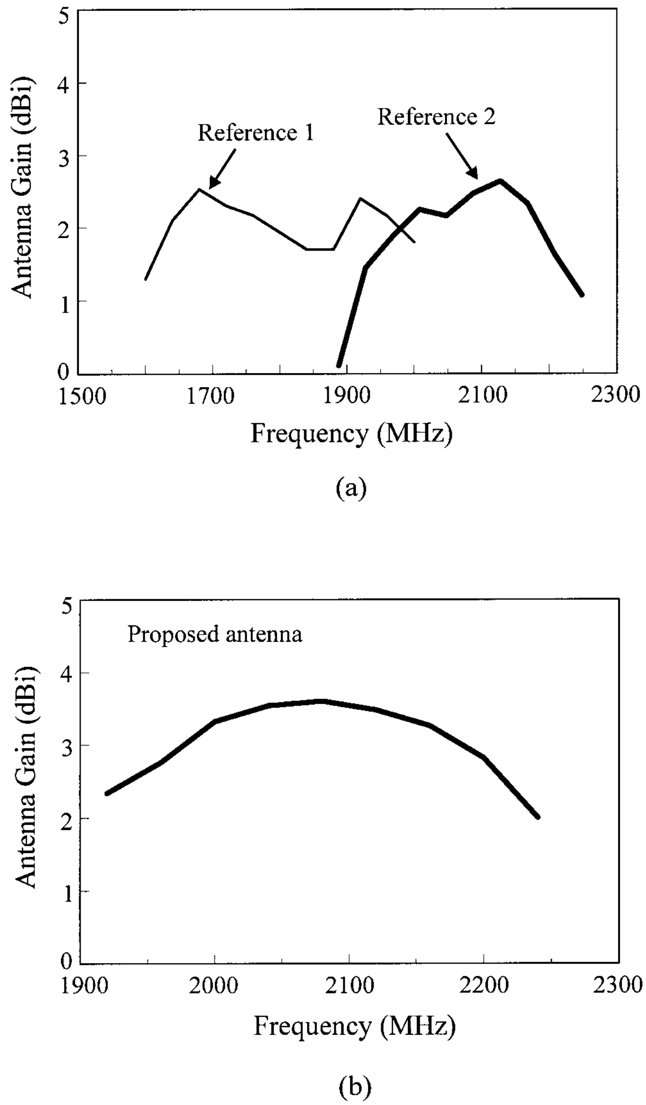

Figure 5 Measured antenna gain for (a) the reference antennas and (b) the proposed antenna

noted that, although the patch size is the same, the operating bandwidth of the proposed design has higher frequencies than the corresponding conventional design of Reference 1. By decreasing the patch size from 15×30 mm^2 to 13×26 mm^2, the conventional design of Reference 2 has an operating bandwidth at frequencies about the same as that of the proposed design.

Figure 3 shows the measured radiation patterns for References 1 and 2 at resonance. No prominent difference in the radiation patterns is observed, although References 1 and 2 have different ground-plane size in wavelength. However, comparison to the measured radiation patterns of the proposed design shown in Figure 4, clearly shows that, in the azimuthal plane (x-y plane), the backward radiation in the direction of $\phi = 180°$ is smaller for the proposed design than for the conventional design. For the vertical plane (x-z plane), it is also clearly observed that the radiation behind the antenna's ground plane is much smaller for the proposed design than for the conventional design. These characteristics suggest that using the proposed design instead of the conventional one can reduce the power absorption in the user's head. Figure 5 also shows the measured antenna gain for frequencies within the operating bandwidths for the reference antennas and the proposed antenna. Both References 1 and 2 show about the same antenna gain level and are lower than that of the proposed antenna by about 1 dBi. The proposed antenna has a peak antenna gain of about 3.5 dBi, and the gain variations are within 1.2 dBi for frequencies within the UMTS band.

4. CONCLUSIONS

A novel shorted patch antenna with an L-shaped ground plane for improving the antenna performance has been proposed. Experimental results of a constructed prototype for operating in the UMTS band have also been presented. The proposed antenna is suitable for applications as an internal mobile handset antenna, and has reduced backward radiation and enhanced antenna gain.

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EXPERIMENTAL STUDY OF A LARGE BANDWIDTH RECTANGULAR MICROSTRIP-FED CIRCULAR SLOT ANTENNA

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ABSTRACT: *A large-band rectangular-shaped microstrip-fed circular slot antenna is studied in this Letter. In this case, many design parameters of this antenna lead to good impedance matching in a wide frequency band. Although the use of a high-relative-permittivity ($\varepsilon_r = 4.3$) substrate usually restricts the operation bandwidth, the measured bandwidth is from 2.277 to 9.272 GHz, which is approximately 124.6 % (VSWR $\leq$ 2.0). The experimented data for the impedance loci and the radiation patterns of the antenna are also described.* © 2002 Wiley Periodicals, Inc. Microwave Opt Technol Lett 33: 316–318, 2002; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.10306

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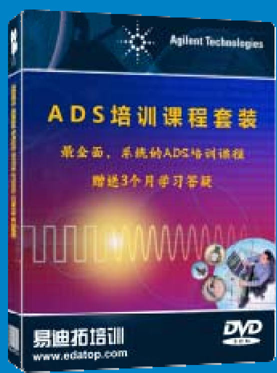

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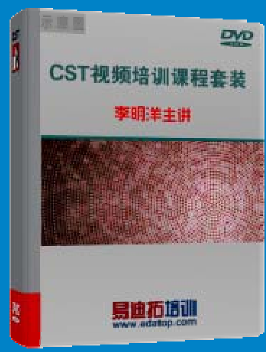

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